† argentatus (Pack.), Proc. Ent. Soc., Phila., 3, 392 (*Sthenopis*). Massachusetts.

Note.—This is perhaps the true *H. argenteomaculatus*, as separated by myself. Harris first notices apply to an Eastern species.

† Behrensii (Stretch), Zyg. Bomb. N. A., 1, 105, Pl. 4, fig. 6 (*Sthenopis*). California.

† montanus (Stretch), Zyg. Bomb. N. A., 1, 105, Pl. 4, fig. 7 (*Sthenopis*). California, (Sierra Nevada).

hyperboreus Mösch., W. E. M., 6, 129 (*Epialus*), Taf. 1, fig. 1; *Hep. pulcher* Grote, Proc. Ent. Soc., Phila., 3, p. 522, Pl. 5, fig. 3. Labrador; Colorado Territory.

† Labradoriensis Pack., Proc. Ent. Soc., Phila., 3, p. 394. Labrador.

† mustelinus Pack., Proc. Ent. Soc., Phila., 3, 393. Eastern States.

gracilis Grote, Proc. Ent. Soc., Phila., 3, p. 522, Pl. 5, fig. 4. Quebec.

† Californicus Boisd., Ann. Soc. Ent. Belg., 12, p. 85. California.

† hectoides Boisd., Ann. Soc. Ent. Belg., 12, p. 85. California.

RESULTS OF AN EXAMINATION OF AN EXPLODED LOCOMOTIVE BOILER, AND OF EXPERIMENTS TO ASCERTAIN THE CAUSES OF EXPLOSION.

By Dr. Charles M. Cresson.

(*Read before the American Philosophical Society, July* 17, 1874.)

The boiler was constructed of No. 1 ($\frac{5}{16}$) boiler iron, single riveted (with the exception of the junction of the waist with the fire-box, which was double riveted); it was of the ordinary locomotive form with enlarged grate surface adapting it for use with Anthracite fuel.

The fire-box had the ordinary flat crown sheet suspended from wrought iron girders by means of bolts $\frac{3}{4}$ in. in diameter, placed $4\frac{1}{2}$ in. apart, the ends of the girders being supported upon the vertical sides of the fire-box. The vertical sheets of the fire-box were stayed by wrought iron bolts $\frac{7}{8}$ in. in diameter, placed 4 in. apart, screwed into the sheets and riveted at the end.

The crown sheet and that part of the boiler directly over the fire-box were connected by stay-rods.

The engine had been run upon a siding to pull out a train of cars, which train being heavier than was ordinarily pulled, the steam-blower was applied for the purpose of increasing the intensity of the fire and generating steam of a higher pressure than was usually employed. But when preparations for starting were completed, it was found, upon reference to the time-table, that the engine would have to remain upon the siding until an expected passenger train had passed. The engineer then left the engine, having first stopped off the steam-blower and observed a steam pressure of about 90 lbs. per square inch.

The boiler exploded between ten and twenty minutes after the engineer had left it. The fireman, who had been cleaning the valves of the sand-box, was at work upon the engine when the explosion took place, and when last seen was standing upon the left side of the engine near the donkey-pump, which was used to supply the boiler with water when the engine was upon the siding. The portion of the boiler immediately over and back of the crown-sheets of the fire-box, and including the back dome, was blown off bodily, the line of fracture passing indiscriminately through the seams and across the sheets.

The seams not torn apart were strained in some places as much as $\frac{1}{4}$ of an inch and opened. The fire-box was blown backwards, carrying with it the back tube-sheet. The remaining portion of the waist of the boiler and the engine were driven forward along the track, the tubes remaining fast in the forward tube-sheet. An examination of the fire-box showed the crown-sheet to have been forced violently downwards, one edge crushing the side-sheets of the fire-box, the other edge and the ends of the crown-sheet remaining nearly in place.

Every stay that was displaced was either fairly broken or drawn through the sheets. There were no signs of undue pressure upon any joint or part of the remaining waist of the boiler, excepting at the line of rupture.

The iron in every part of the boiler appeared in good condition, without signs of burning or heating, except in one lower corner of the fire-box, which part, however, was not ruptured or affected by the explosion. Trial pieces of the iron cut from several parts of the fire-box and waist-sheets exhibited good fracture, the lowest tensile strength found was 51,000 lbs. to the square inch.

After a careful examination of the wreck, and of the results of my own experience, I have arrived at the conclusion that the explosion of this boiler was caused by the projection of water upon the heated crown-sheet. The crown-sheet of the furnace was most probably heated to a temperature of between 500° and 600° Ft., in consequence of a neglect to keep the water in the boiler at the proper height.

This temperature, not sufficient to produce a spheroidal state of the water thrown upon the crown-sheet, allowed of enough heat to be stored up and given out suddenly to cause steam of very high pressure to be instantly generated, so that the rear portion of the boiler was blown to pieces before a sufficient time had elapsed to allow of the distribution of the expansive force throughout the waist. By reference to the results of experiments detailed in the following paragraphs, it will be seen that an average of $\frac{23}{100}$ of an inch of depth of water over the crown-sheet could readily be converted into steam in one second of time, and would produce a pressure of over 570 lbs. per square inch in addition to that already existing in the boiler.

The sudden opening of any outlet of pressure, such as the safety-valve, throttle, whistle, blower or steam-cock to the donkey-pump, would produce a foaming or disturbance of the water-level in the water-space surrounding the fire-box, causing the water to flow over the crown-sheet in an amount quite sufficient to account for the disaster under the conditions indicated.

To illustrate the rapidity of the explosive force, let us suppose the upper surface of the crown-sheet of the fire-box to have been covered with gunpowder to a depth equal to that of the water, which we have shown could have been evaporated by it. If this powder were ignited in the ordinary way, it would require from half a second to two seconds for its complete combustion, according to the quality of the powder, whereas an equal quantity of water thrown upon the crown-sheet could be converted into steam in less than one second, the resulting volume of vapor being nearly equal in both cases.

Careful examination of the quality of the iron, and of the plan of construction of the boiler, have convinced me that the boiler was amply strong for the purposes designed. I am of the opinion that the disaster occurred directly and solely from a neglect to keep the water within the boiler at its proper level.

The tests and experiments made, upon which the foregoing opinion was founded, are as follows :

A.—Tests of Strength of Iron.

Test pieces cut from the worst looking part of the side-sheet of the fire-box gave the following results :

a.—With the length of the sheet. Dimensions of breaking section :

Thickness	0.302	inch.
Width	0.402	"
Original length of piece	2.800	"
After fracture	2.943	"
Length of section extended	1.000	"
Extension	0.143	"
Breaking wt. per sq. in	54,300	lbs.

b.—Cut across the sheet. Dimensions of breaking section :

Thickness	0.308	inch.
Width	0.409	"
Original length of piece	2.790	"
After fracture	2.890	"
Extension	0.100	"
Breaking wt. per sq. in	51,200	lbs.
Length of section extended	1.000	inch.

B.—Experiments Upon Hot Plates.

The sampl s employed were cut from the crown-sheet bars of the exploded boiler. To ascertain their specific heat, and the amount of heat they were capable of imparting to water in a given time, the samples were heated in a mercury bath at various temperatures, and then plunged into a weighed amount of water and the rise of temperature carefully ascertained by a thermometer graduated to $\frac{1}{10}$° Ft.

To ascertain the amount of heat imparted by the iron in a given time, the samples were immersed by securing them to a cross-arm fixed to a heavy pendulum of such length as to vibrate in the desired time and averaging the results of many observations.

As these experiments were to ascertain the lowest probable capacity of the iron in the crown-sheet for storing and giving out heat, no great care was taken to prevent radiation of heat from the iron in its passage from the mercury bath to the water, nor of radiation from the water bath during the experiment; the results do not, therefore, by any means, express the full amount of heat to be derived from the samples.

Calculations of the amount of steam generated in a given time by iron under the conditions stated, must therefore fall short of the practical effect produced, and if the conditions assumed for experiment show that steam could have been generated in sufficient quantity and with sufficient rapidity to have destroyed the boiler, we can safely conclude that the actual destructive effect was greater than that expressed by our results.

The specific heat of iron is given in the tables at an average of 0.1200 that is, that eight times as much heat is required to raise one pound of water through a given number of degrees as will suffice to raise one pound of iron through a similar number of degrees. For example, 8 lbs. of iron losing 100° Ft. of temperature will elevate the temperature of 1 lb. of water 100° Ft. By the formula:

$$\frac{\text{Wt. of Water}\begin{pmatrix}\text{Temp. of Water}-\text{Temp. of Water}\\ \text{before immersion}\quad\text{after immersion}\end{pmatrix}}{\text{Wt. of Iron}\begin{pmatrix}\text{Temp. of Iron}-\text{Temp. of Iron}\\ \text{before immersion}\quad\text{after immersion}\end{pmatrix}}=\text{S. H.}$$

I have determined the specific heat of the sample of iron cut from the boiler to be 0.113 at a temperature of 212° Ft., and as it is considerably greater at higher temperatures, I have therefore assumed it to average $\frac{1}{8}$ that of water.

Experiments made with gunpowder to ascertain the rapidity of explosion, showed that with various kinds of gunpowder the time required for complete ignition of a thin stratum of powder, spread over a surface equal to the area of the crown-sheet, when ignited at one edge only, varied from one-quarter of a second to one and a half seconds; and as the destructive effects are most impressive to the popular mind, they serve to illustrate the effects that can be produced by converting water into steam as the increase in volume is about the same, that is, 1700 volumes of vapor are produced by the combustion of gunpowder, and 1700 volumes of vapor of atmospheric tension are generated by the conversion of water into steam.

The experiments alluded to of immersing a sample of the iron whilst heated into water, were made chiefly with a sample weighing 2,914 grains heated to a temperature of 500°@520° Ft., and immersed in a body of water weighing 29,140 grains (ten times the weight of the iron). Some of the results were as follows :

Time of immersion	1 second.
Expt. No. 1, rise of temp. of water	2.9° Ft.
" " 2, " " "	2.7° "
" " 3, " " "	2.8° "
" " 4, " " "	2.8° "
" " 5, " " "	2.7° "
" " 6, " " "	2.8° "
" " 7, " " "	2.9° "
" " 8, " " "	2.9° "
" " 9, " " "	2.7° "
Average	2.8° Ft.

Or 2,914 grains of iron were capable of imparting 28° Ft. to an equal weight of water in one second of time.

The weight of the crown-sheet was	300 lbs.
Bars and studs attached was	810 "
Total	1110 lbs.

This mass of iron could therefore impart 28° Ft. to 1110 lbs. of water in one second of time, or could have converted 32 lbs. of water into steam.

For an example, let us suppose the crown-sheet and bars to have been heated to a temperature of 514° Ft., and that we have flowed over it an amount of water sufficient to reduce the temperature of the iron to 423° Ft., corresponding to a pressure of steam of 300 lbs. to the square inch, and which suddenly added to the pressure already existing in the boiler must severely try the boiler, if not tear it apart.

Then, Temp. of Iron	514° Ft.
Reduced to	423° Ft.
Fall of temperature	91° Ft.

Then $1{,}110 \times 91 = 101{,}010$ units of heat given out by the iron ; this divided by $8 = 12{,}626$ lbs. of water heated 1° Ft., and this divided by the latent heat of steam at 423° Ft., plus the difference between the sensible heat at 90 lbs. and at 300 lbs. $= 913$, gives 13.8 lbs. of water as the amount converted into steam at 300 lbs. pressure.

The area of the crown-sheet=22 sq. ft. this amount of water (13 8 lbs.) would cover it to a depth of 0.12 inches, and when expanded into steam of one atmosphere of tension would occupy a space equal to a prism having the crown-sheet for its base and 204 inches in height. The average steam space above the crown-sheet is 10 inches, and the compression of the 204 inches of steam into 10 inches would give a pressure of 20.2 atmospheres or 300 lbs. per square inch momentarily added to that of 90 lbs. already existing in the boiler. The cross-section of the strain above the crown-sheet is 42 inches. Thickness of the iron $\frac{5}{16}$ of an inch, or total section of iron to be broken $\frac{5}{8}$ of an inch. Breaking weight from experiment=54.400 lbs. per sq. in.

Then $\dfrac{54000 \times 5}{\frac{8}{42}}$ } Breaking strain of perfectly stayed$=\frac{34000}{42}=810$ pounds per sq. in.

Deducting 20 per cent. for rivets=648 lbs. per sq. in., or, according to Fairbairn, deducting 44 per cent. for single riveted joints=454 lbs. for bursting strains.

Let us now suppose the crown-sheet and bars to have been heated to a temperature of 660° Ft., and to be reduced to 485° Ft., the loss of temperature—175° Ft. Then $175 \times 1{,}110 = 194{,}250$ heat units, or $\div 8 = 24{,}281$ lbs. of water heated 1° Ft.

Sensible heat of steam at 570 lbs. =	485°
" " " 90 lbs. =	335°
Difference	150°

This added to the latent heat of steam at 570 lbs. = (777° + 150° =) 927° as the units of heat necessary to convert water at 335° Ft. into steam at 485° Ft.

Then $24{,}281 \div 927 = 26.19$ lbs. of water converted. This amount of water would cover the crown-sheet to a depth of 0.228 inches, and would yield an amount of steam of atmospheric tension sufficient to occupy a space equal to a prism having the crown-sheet for its base and 387 inches in height.

When compressed into a height of 10 inches this steam would suddenly add a pressure of 38 atmospheres or 570 lbs. per square inch to the previous pressure of 90 lbs. per square inch, and would give a total pressure exceeding the 648 lbs. per square inch in the maximum of force necessary to tear the boiler apart, as derived from experimental trials of the strength of iron.

I have endeavored by experiment to fix the temperature at which iron, with such a surface as that from this boiler, will produce a spheroidal state in water flowed upon it. When the samples of iron were floating upon boiling mercury (662° Ft.) they failed to repel the water but converted it rapidly into steam.

The specific heat of iron, at high temperatures, averagiag about 0.122, and its specific gravity 7.8, we can assume that an iron plate will raise the temperature of a stratum of water in contact with one surface, and of its own thickness in depth, 1° Ft. for every degree that it loses in temperature, or that it will convert about $\frac{1}{1000}$ of that amount of water at the boiling point into steam of high tension.

The crown-sheet of the furnace of this locomotive, with its stays and girders, weighed 1,110 lbs., and had a surface of 22 square feet, this gives a mass of iron equal to an average of 50.45 lbs. per square foot, or an average thickness of 1.23 inches of iron plate.

Such a plate could therefore raise a stratum of water 1.23 inches in depth 1° Ft. for every 1° Ft. of temperature lost by the iron, or would convert a stratum of water 0.00123 inch in depth into steam.

In our second example, we supposed the temperature of the iron to have fallen from 660° Ft. to 485° Ft., a loss of 175° ; this would give us $0.00123 \times 175 = 0.21525$ inch as the depth of water converted into steam, and which, under the conditions stated, would give a pressure of nearly 37 atmospheres in addition to that already existing within the boiler by the transfer of heat from the iron.

This leads to the conclusion that the substitution of a crown-sheet $\frac{3}{16}$ inch thick, stayed without girders, would require the contraction of the space between the crown-sheet and the roof of the boiler to an average of $2\frac{3}{4}$ inches, to allow of the sudden production of a pressure of steam equal to that capable of development in a boiler constructed as was the one exploded, or the effect of an equally overheated crown-sheet would be reduced to $\frac{1}{4}$ of that which would otherwise have been produced.

That such is the fact was clearly shown by the result of a recent accident to another locomotive in which the crown-sheet was simply forced down, as by a gradual increment of pressure tearing out the stay-bolt and permitting the steam and water to escape into the fire-box and extinguish the fire without further injury to the boiler or engine.

C.—Level of Water in Boilers. (How Affected.)

There are several conditions under which an engineer may be deceived as to the level of the water in the boiler of a locomotive-engine. The most important are :

1. Priming or rise of water-level.
2. Changes of grade.
3. Variations in the speed of the engine.

In all boilers the level of the water is somewhat raised whenever steam is taken off. The amount of the rise is varied by the rapidity with which steam is conveyed away : the form of the boiler and the manner in which heat is applied for the production of steam.

In boilers in which there are narrow water spaces surrounding the fire-box, and those in which heat is conveyed to the water locality, that is, the heating surfaces are small in extent as compared with the whole volume of water, and are very hot, the lift of the water is very considerable whenever an outlet for steam is opened, amounting in some instances to as much as 12 and 14 inches.

In ordinary locomotive boilers the rise upon opening the throttle or safety-valve averages about 4 inches.

The presence of oil in the boiler greatly increases the foaming. The influence of changes of grade is rarely considered by locomotive engineers. The change from a level road to an ascending grade of 100 feet per mile would cause the water in the boiler to flow back to the fire-box end so as to raise the water-level about $1\frac{3}{4}$ inches, depressing the water-level forward by the same amount or a total variation of $3\frac{1}{2}$ inches.

If the level of the water be found at the top gauge whilst the engine is running with unvarying velocity up a grade of 100 feet per mile, and the engine be stopped upon a descending grade of 100 feet per mile, the actual level of the water over the crown-sheet of the fire-box would be $11\frac{1}{2}$ inches below the top gauge-cock.

If the first observations had indicated one gauge of water only, the actual level of the water, after the engine had been stopped on the descending grade, would be far below the level of the crown-sheet.

From observations made upon an engine by means of a glass gauge on the water column, I have found that the water-level is greatly disturbed during the running of the engine by every change of speed. Whilst at rest the water surface is level ; upon starting the engine the water does not take up the motion immediately, but is crowded to the back part of the boiler, and remains so in a greater or less degree until the motion is checked, when the water at first becomes level and then crowds towards the front end of the boiler until the engine is stopped, when its surface becomes level. Running at a speed of about 25 miles an hour, first forward and then backward, the variation at the water-level was about four inches.

D.

A record has been made of the effect of injecting fresh water into boilers containing hot concentrated solutions of various salts ; but as analysis of the water supplied to this engine show that they contain but a moderate percentage of salts in solution, it is unnecessary to give the results of the experiments, as the effect produced in practice would add but little to the destructive forces already fully explained, and which are of themselves more than sufficient to account for explosions under the conditions stated.

AN OBITUARY NOTICE OF CHIEF JUSTICE JOHN MEREDITH READ.

By Eli K. Price.

(*Read before the American Philosophical Society, December* 18, 1874.)

It is within the scope of our comprehensive charter to commemorate the life and character of our deceased members. To do so is to promote knowledge, and to render service to science and society. It is thus the dead shall yet speak, and through our press speak to the most intelligent of the civilized world, and to such in future times.

He whose memory we would perpetuate to-night was a most diligent student and able administrator of the science of jurisprudence ; that